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DECONTAMINATION OF PCB CONTAMINATED TRANSFORMERS USING OIL

Report No. 91-206-K

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ABSTRACT

A preliminary investigation was performed to assess the potential of insulating oil (Voltesso 35) for decontaminating PCB contaminated transformers. The release of PCBs from dismantled components of transformers containing 177 and 1180 ppm PCB contamination in the original oil, and from an intact 1170 ppm drained transformer was monitored. Immersion in oil led to a uniform redistribution of the PCBs associated with the porous materials. Residual contamination level in the materials was consistent with their oil absorption capacities. The release process appears to occur in two distinct steps: an initial washout effect followed by a temperature dependent diffusional release. In contrast to PCBs in porous materials, adsorbed PCBs on metal surfaces desorb readily; contact times required are in the order of hours rather than days as in the case of the porous materials. Provided sufficient time to equilibrate is allowed, the effectiveness of the decontamination is solely determined by the operating oil to solids ratio.

job	file	date	report no.
32-510-100	837.34	November 13, 1991	91-206-K

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EXECUTIVE SUMMARY

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A.Husain and R. Mowat

Ontario Hydro has a large number (about 300,000) of pole-top transformers of different sizes distributed in the Province. The mineral oil contained in these transformers is contaminated with PCBs. While most of the units have a PCB level of less than 50 ppm (mg/Kg), about 10% of the units contain PCBs in excess of 50 ppm. Transformers with less than 50 ppm PCBs are categorized as PCB-free while those exceeding 50 ppm are considered contaminated.

The presence of PCBs in the transformers requires that scrapped PCB contaminated units be disposed of in an environmentally appropriate manner. Currently, disposal of such transformers follows an interim guideline issued by the MOE in 1986. Under that guideline, equipment containing less than 2500 L of oil with between 50 and 500 ppm PCB is considered to be decontaminated when all free liquid is removed, the unit allowed to stand for a minimum of 24 h and any additional free liquid accumulation removed. Accordingly, pole top transformers with 50-500 ppm contamination are drained at Area and District Service Centres before being shipped to Kipling for disposal for their scrap metal value, while those exceeding 500 ppm are stored 'as is' or after draining at the Service Centres. Pole top transformers with <50 ppm contamination are drained locally or sent to the Kipling facility for draining and are then disposed.

The interim MOE guideline was issued in 1986 on the understanding that formal decontamination guidelines then under development would be issued. These formal guidelines were never issued and in mid 1990 it was learnt that previous permissions to drain and decontaminate small equipment might be rescinded in the future. The MOE's position appears to be that current methods of decontamination are not sufficiently effective for nonhazardous waste disposal. The porous insulation materials and wood in the cores remain PCB contaminated and thus constitute PCB waste. Accordingly, MOE may in future disallow the current disposal practice for small equipment. In the absence of an approved decontamination method, the net impact of MOE's ruling would be a significant increase in PCB solid waste requiring storage.

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A research program to develop decontamination procedures (the need for developing this technology was identified in a recent PCB Destruction Task Group report) was already underway at the time MOE's proposed new ruling was learnt of. The focus of the program which initially was to address the >500 ppm category of transformers was expanded, therefore, to include the 50 to 500 ppm population. The first phase of the program reported earlier involved a detailed assessment of the PCB inventory in pole-top transformers. Decontamination of transformers, addressed in the second phase, is reported here.

In Phase 1, the inventory and distribution of PCBs in a number of PCB contaminated pole top transformers were measured. The transformers varied in make, size and kVA ratings. Their bulk oil contamination levels ranged between 34 and 1790 ppm. About 95 % of the PCB inventory in the drained units resided within the porous insulation with the balance being associated with the nonporous metallic surfaces. The PCB in the porous insulation is associated principally with absorbed oil. The adsorbed PCBs on the steel surfaces followed a Freundlich adsorption isotherm. The total PCB inventory was observed to be linearly related to the product of the bulk oil contamination level and the weight of the drained transformer.

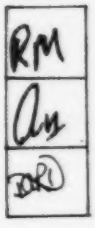
This report documents preliminary results obtained in support of the second objective stated above. Oil was selected as the decontamination fluid because Ontario Hydro's sodium based decontamination facility is available to treat the resulting waste oil. The release of PCBs from dismantled transformer components immersed in insulating oil (Voltesso 35) and from an intact drained transformer filled with fresh insulating oil were investigated. The dismantled components originated from two transformers which were autopsied in Phase 1. The transformers had oil contamination levels of 177 and 1180 ppm PCB, respectively. The intact transformer investigated had an oil contamination level of 1170 ppm.

Immersion in oil led to a uniform redistribution of the PCBs associated with the porous materials. Residual contamination levels in the materials was consistent with their oil absorption capacities. The release process appears to occur in two distinct steps: an initial washout effect followed by a temperature dependent diffusional release. In contrast to PCBs in porous materials, adsorbed PCBs on metal surfaces desorb readily with contact times required being in the order of hours rather than days as in the case of the porous materials. Provided sufficient time for equilibration is allowed, the effectiveness of the decontamination is

solely determined by the operating oil to solids ratio. Depending upon the regulatory targets (currently 50 ppm), the quantity of oil for each soaking and the number of oil changes needed can be adjusted to achieve the required degree of decontamination.

The decontamination process can be applied directly to an undismantled transformer or as a tail end process to clean up residual contamination in dismantled materials.

Further development of the process is strongly recommended but should be deferred until a complete assessment of existing decontamination technologies is performed.



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To Mr. D.A. Lee
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1.0 INTRODUCTION AND BACKGROUND

Ontario Hydro has a large number (about 300,000) of pole-top transformers of different sizes distributed in the Province. The mineral oil contained in these transformers is contaminated with PCBs. While most of the units have a PCB level of less than 50 ppm (mg/Kg), about 10% of the units contain PCBs in excess of 50 ppm. Transformers with less than 50 ppm PCBs are categorized as PCB-free while those exceeding 50 ppm are considered contaminated.

The presence of PCBs in the transformers requires that scrapped PCB contaminated units be disposed of in an environmentally appropriate manner. Currently, disposal of such transformers follows an interim guideline issued by the MOE in 1986/2/. Under that guideline, equipment containing less than 2500 L of oil with between 50 and 500 ppm PCB is considered to be decontaminated when all free liquid is removed, the unit allowed to stand for a minimum of 24 h and any additional free liquid accumulation removed. Accordingly, pole top transformers with 50-500 ppm contamination are drained at Area and District Service Centres before being shipped to Kipling for disposal for their scrap metal value, while those exceeding 500 ppm are stored 'as is' or after draining at the Service Centres. Pole top transformers with <50 ppm contamination are drained locally or sent to the Kipling facility for draining and are then disposed.

Drained transformer carcasses are disposed of as scrap for their metal recovery value. At the scrap yard, any additional fluid accumulations are removed, the casings compacted and shredded for melting and reuse, the core steel manually separated and shredded for melting and reuse and the coil incinerated to burn off insulation for the recovery of valuable copper windings.

The interim MOE guideline was issued in 1986 on the understanding that formal decontamination guidelines then under development would be issued. These formal guidelines were never issued and in mid 1990 it was learnt that previous permissions to drain and decontaminate small equipment might be rescinded in the future. The MOE's position appears to be that current methods of decontamination are not sufficiently effective for nonhazardous waste disposal. The porous insulation materials and wood in the cores

remain PCB contaminated and thus constitute PCB waste. Accordingly, MOE may in future disallow the current disposal practice for small equipment. In the absence of an approved decontamination method, the net impact of MOE's ruling would be a significant increase in PCB solid waste requiring storage.

A research program to develop decontamination procedures (the need for developing this technology was identified in a recent PCB Destruction Task Group report /3/) was already underway at the time MOE's proposed new ruling was learnt of. The focus of the program which initially was to address the >500 ppm category of transformers was expanded, therefore, to include the 50 to 500 ppm population. The program had a two-fold objective: 1) develop a detailed assessment of the PCB inventory in pole-top transformers with contamination levels up to 2000 ppm, and 2) investigate the decontamination of transformers.

Work in support of the first objective was recently reported/4/. The inventory and distribution of PCBs in a number of PCB contaminated pole top transformers were measured. The transformers varied in make, size and kVA ratings. Their bulk oil contamination levels ranged between 34 and 1790 ppm. About 95 % of the PCB inventory in the drained units resided within the porous insulation with the balance being associated with the nonporous metallic surfaces. The PCB in the porous insulation is associated principally with absorbed oil. The adsorbed PCBs on the steel surfaces followed a Freundlich adsorption isotherm. The total PCB inventory was observed to be linearly related to the product of the bulk oil contamination level and the weight of the drained transformer.

This report documents preliminary results obtained in support of the second objective stated above. Oil was selected as the decontamination fluid because of the availability of Ontario Hydro's sodium based decontamination facility to treat the resulting waste oil. The release of PCBs from dismantled transformers components immersed in insulating oil (Voltesso 35) and from an intact drained transformer filled with fresh insulating oil was investigated.

Previous work at OHRD /5-8/ focussed mostly on the decontamination of askarel filled transformers and capacitors; the solvents examined included No. 2 fuel oil and trichloroethylene. Cleaning of PCB contaminated transformers was only briefly investigated. A 15 kVA transformer containing insulating oil with a PCB concentration of 150 ppm was autopsied: drainage removed 98 % of the oil and associated PCBs; a subsequent trichloroethylene wash of the core removed 98 % of the PCBs remaining after drainage.

A recent EPRI study/9/ investigated the decontamination of PCB contaminated pole top transformers using insulating oil. Three transformers with oil contamination levels of 235, 337 and 365 ppm PCBs, respectively, were refilled with fresh oil; the PCB content in the new oil was monitored with time. The 235 ppm transformer, energized (without loading) to excite/vibrate the core achieved equilibrium within a day. The unit with

337 ppm contamination level was left to stand at room temperature and achieved equilibrium within 60 days. The last transformer was loaded to reach a temperature of 80^{0}C and equilibrated within one day. In all cases, the equilibrium level achieved corresponded to the uniform redistribution of the original PCB inventory in the insulations and on the nonporous metal surfaces.

2.0 RELEASE OF PCBs FROM DISMANTLED TRANSFORMER COMPONENTS IMMERSED IN OIL

Materials from two previously autopsied transformers (see Table 1 for details) were immersed in oil (Voltesso 35) under static conditions for prolonged durations at temperatures up to 50^{0}C. The oil was periodically sampled (briefly agitated before sampling) and analysed for PCBs. At the end of the exposures, the materials were extracted in isooctane to determine their residual PCB content. Because of the low contamination levels on core steel surfaces, the increase in the PCB level of oil as a result of their immersion was not measurable. Therefore, separate samples of core steel were immersed in oil for varying durations and then swiped using isooctane-wetted Kimwipes to assess their residual surface contamination levels.

TABLE 1

TRANSFORMERS INVESTIGATED+

SERIAL NO.	MAKE	KVA	PCB (PPM)*	PCB TYPE
5612-43	FED/PIONEER	50	177	1254
54252	SUPREME	5	1180	1260
54251	SUPREME	5	1170	1260

+ The first two transformers were previously autopsied; the last transformer was used to assess the effectiveness of in-situ decontamination
* Units of ug/g;

Characteristics of selected materials from the 177 and 1180 ppm transformers as previously determined /4/ are shown in Table 2. Decontamination results are shown in Tables 3 & 4 and Figures 1 & 2. Note the weight of material (column 2) in Tables 3 & 4 includes the absorbed oil present in the materials and the weight of oil (column 3) refers to the amount of insulating oil used during each immersion. The decontamination factors (DFs) in Tables 3 & 4 were calculated from the expression ((PCB released + Residual PCB)/ Residual PCB) where the sum in the numerator represents the initial PCB inventory in the solid. The inventories were generally consistent with the previous measurements/4/ indicated in Table 2.

2.1 Decontamination of 177 ppm Transformer Materials

Consider the results in Table 3 and Figure 1. Based on their previously determined PCB inventories (see Table 2) /4/, the pressboard and the green and brown papers, at equilibrium, were estimated to leach 31, 29 and 50 ug PCB per gram material, respectively. Thus, as shown in Figure 1(a), within the duration of the experiments, equilibrium levels were reached in the cases of both papers but not in the case of the pressboard (note that data for corrugated strips is not shown in Figure 1 because the measurements were below the detection limit of 2 ppm). Therefore, the DF for the pressboard was much lower than that obtained for the other materials. Note that the weight ratio of oil used for immersion to solids immersed were 3.5, 3.4 and 5.4 for the pressboard, green paper and brown paper, respectively. If this ratio was 5.4 in each case, the DFs assuming uniform redistribution would have been 4.5 for the pressboard and 12.5 for both papers.

Figure 1(b) shows that the initial release of PCBs from the solids was linear when plotted against square root of time. This is consistent with a diffusional mechanism for the release process. In the case of the green paper, the positive intercept indicates a small washout effect possibly due to adhering oil on the surface of the paper.

TABLE 2

CHARACTERISTICS OF SELECTED TRANSFORMER MATERIALS/4/

Material	Thickness (mm)	% Oil*	ug PCB/g Oil in Material	ug PCB/g Material	ug/PCB/ ug/100cm^2
177 ppm Transformer					
Core Steel	-	-	-	-	1.2
Pressboard	8.1	18.0	98	17.7	-
Corrugated Strips	1.6	2.8	107	3.0	-
Paper (Green)	0.3	25.0	168	41.8	-
Paper (Brown)	0.25	35.3	167	58.9	-
1180 ppm Transformer					
Core Steel	-	-	-	-	5.1
Pressboard	1.3	25.0	647	161	-
Paper	1.1	16.6	975	171	-
Wood	9.1	22.7	681	155	-
Plastic	0.85	6.2	479	30	-

* Oil absorbed in material

Under current guidelines, only the brown paper would be considered a PCB waste since its contamination level before decontamination exceeds 50 ppm (see second last column in Table 2). Immersion in oil was sufficient to reduce the contamination level to below regulatory concern. If a proposed 2 ppm limit comes in to effect, then all the materials from the 177 ppm transformer listed in Table 2 would constitute PCB waste. Decontamination to below regulatory concern would require one oil immersion employing an increased oil/solid ratio or a second similar drain and soak procedure.

Experiments involving core steel employed an oil to metal weight ratio of about 1.5 (specific surface of core steel 9.9 cm^2/g). Samples swiped prior to decontamination had 0.62 ug PCB/100 cm^2 (note this value differs from the previous measurement/4/ shown in Table 2) while those exposed to oil at 25^0C for durations ranging between 1 and 30 h had 0.071 $\pm$ 0.06 ug/100 cm^2 yielding an overall DF of 8.7.

2.2 Decontamination of 1180 ppm Transformer Materials

Consider the results in Table 4 and Figure 2. Based on their previously measured PCB inventories /4/, the pressboard, paper, wood and plastic materials, at equilibrium, are expected to leach 285, 175, 350 and 50 ug PCB per gram, respectively. As shown in Figure 2, equilibrium levels were reached within the experimental duration in all cases. Note that the DFs obtained differ solely due to the weight ratio of oil to solids used in the immersion experiments.

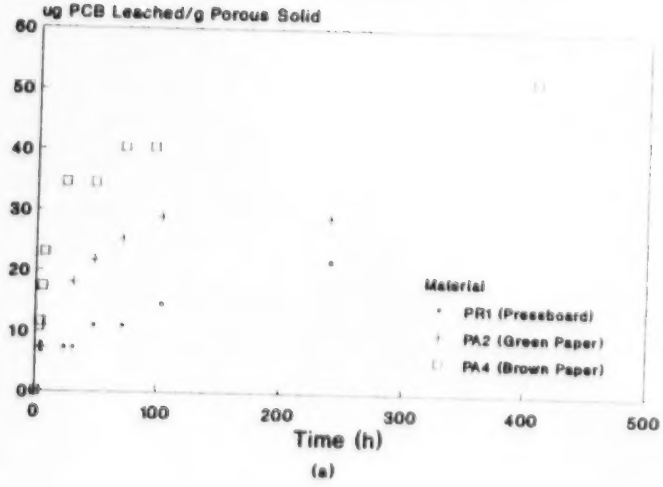
TABLE 3

IMMERSION OF 177 PPM TRANSFORMER MATERIALS IN OIL - DECONTAMINATION FACTOR

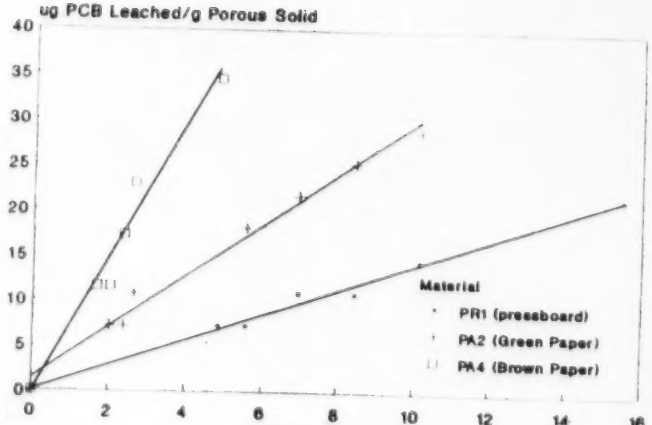
Material	Weight (g)	Oil (g)	PCB Released (ug/g)+	(ug)	Residual PCB (ug/g)*	(ug)	DF$
Pressboard	113.75	397.52	6	2385	11.10	1261	2.9
Corrugated Strips	99.52	497.39	<2	-	0.14	14	21.1**
Green Paper	100.19	343.27	8	2746	3.97	398	7.9
Brown Paper	58.09	314.16	9	2827	4.22	245	12.5

+, ug per g oil; *, ug per g solid; $, Decontamination Factor
**, DF estimated from previously measured/4/ inventory (see Table 2)

As indicated in Figure 2 the initial phase of the decontamination was performed at 25^0 C. Subsequently, the oil temperature was raised to 40^0C and then to 50^0C. At the end of the initial phase the rate of PCB release from all the materials with the exception of wood appeared to have levelled off. However, the subsequent increase in temperature caused additional releases to occur. Without the increase in temperature the duration to achieve equilibrium would likely have been much longer.



(a)



(b)

Figure 1 Desorption of PCBs (type 1254) - Materials from 177 ppm Transformer

As in the case of the 177 ppm transformer materials, Figure 2(b) shows that the initial release of PCBs from the solids was linear when plotted against square root of time, consistent with a diffusional mechanism for the release process. As before, the positive intercept in the case of the paper indicates a small washout effect possibly due to adhering oil on the surface of the paper.

Under current guidelines, all the materials excepting the plastic would be considered a PCB waste since their initial contamination level before decontamination exceeds 50 ppm (see Table 2). The results indicate that for all the materials an extended immersion in oil was sufficient to reduce the contamination level below regulatory concern. If the proposed 2 ppm guideline comes in to force, then all the above materials before decontamination constitute PCB waste. After one oil immersion, all the materials except the plastic would remain contaminated. A second drain and soak procedure would be required in the case of these materials. For the paper and wood, the second exposure would need to employ a larger oil to solids ratio to achieve the desired degree of decontamination.

Experiments involving samples of core steel employed an oil to metal weight ratio between 1.5 and 2.0 (specific surface of core steel 8.6 cm^2/g). Compared to the initial contamination level of 5.1 ug/100 cm^2, those exposed to oil at 25^{0}C for durations ranging between 1 and 72 h had 0.47 $\pm$ 0.11 ug/100 cm^2 contamination yielding an overall DF of 10.9.

An attempt was made to estimate the overall decontamination factor that would be obtained by drain and soak of all the materials from the 177 ppm

TABLE 4

IMMERSION OF 1180 PPM TRANSFORMER MATERIALS IN OIL - DECONTAMINATION FACTOR

Material	Weight (g)	Oil (g)	PCB (ug/g)+	Released (ug)	Residual PCB (ug/g)*	(ug)	DF$
Pressboard	39.05	290.08	39	11313	3.74	146	78.6
Paper	91.76	350.52	39	13670	33.01	3029	5.5
Wood	56.01	256.50	70	17955	45.80	2565	8.0
Plastic	35.06	241.90	7	1693	1.51	53	32.9

+, ug per g oil; *, ug per g solid; $, Decontamination Factor
**, DF estimated from previously measured/4/ inventory (see Table 2)

and 1180 ppm transformers under conditions similar to those employed in the above batch studies. For this purpose the detailed PCB inventory developed in Phase 1 /4/ was utilised to estimate the average contamination levels associated with the porous and nonporous materials before and after decontamination. The levels after decontamination were obtained by assuming appropriate values for the DFs of various materials. Considering

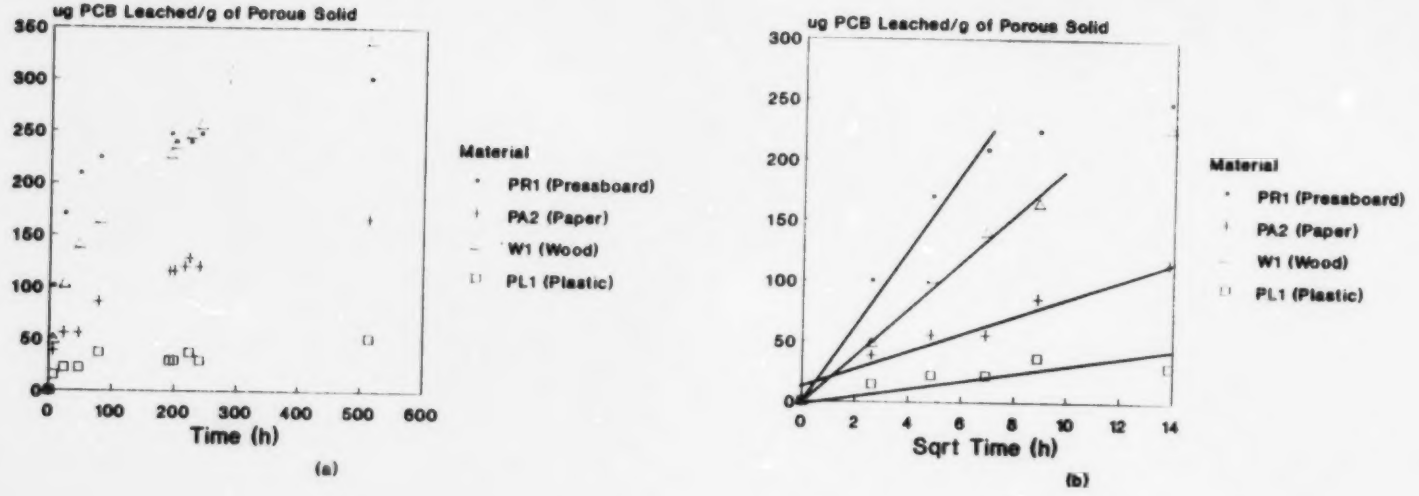


Figure 2 Desorption of PCBs (type 1260) - Materials from 1180 ppm Transformer

(0-191h, 25 deg C; 191-336h, 40 deg C; >336h, 50 deg C)

the 177 ppm transformer, for instance, a DF of 8.7 was assumed for all nonporous surfaces, a DF of 2.9 was assumed for all pressboards, an average value of 10.2 was assumed for all papers etc.

Results obtained are shown in Table 5. Note that the average contamination level of the porous materials from the 177 ppm transformer prior to decontamination was less than 50 ppm. Results suggest overall DFs of about 6-7 for the porous materials. In the case of the 1180 ppm transformer, although decontaminated materials may individually exceed the 50 ppm limit, on an overall basis their average contamination level can be expected to be below the regulatory limit.

The 177ppm and the 1170 ppm transformers had oil capacities of approximately 62 and 23 kg, respectively. If these were intact and had been filled with oil to their capacities, the operating oil to solid ratio for the porous materials would be about 4 and 0.8, respectively. Therefore, a single drain and soak for the 177 ppm transformer would decontaminate the porous materials by a factor exceeding that reported in Table 5 while in the case of the 1180 ppm transformer the DF would be lower than that reported in Table 5. In the latter case a second drain and soak cycle would thus be necessary.

TABLE 5

DECONTAMINATION OF TRANSFORMER MATERIALS - EXPECTED OVERALL RESULTS

	177 ppm Transf.	1180 ppm Transf.
Wt. of Porous Materials (g)	15,652	28,704
PCB present in Porous Materials (ppm)		
Before Decontamination*	18	192
After Decontamination+	3	28
Decontamination Factor	6	6.9
Area of Nonporous Materials (m^2)	20.3	27.6
PCB on Nonporous Materials (ug/100 cm^2)		
Before Decontamination*	1.3	11.1
After Decontamination+	0.15	1.0

* Based on detailed inventory in Ref. 4.
\+ Based on detailed inventory in Ref. 4 and measured DFs.

3.0 ESTIMATED DIFFUSION COEFFICIENTS

The experimental leaching results were interpreted based on diffusional mass transport with an effective diffusivity D defined as:

$$\frac{A}{A_o} = \sqrt{\left[\frac{4Dt}{\pi}\left(\frac{S}{V}\right)^2\right]} \qquad (1)$$

where A is the PCB released in the elapsed time t
A_0 is the initial inventory of PCB in sample
S/V is the surface to volume ratio of the solid (equals 2/sheet thickness for thin sheets)

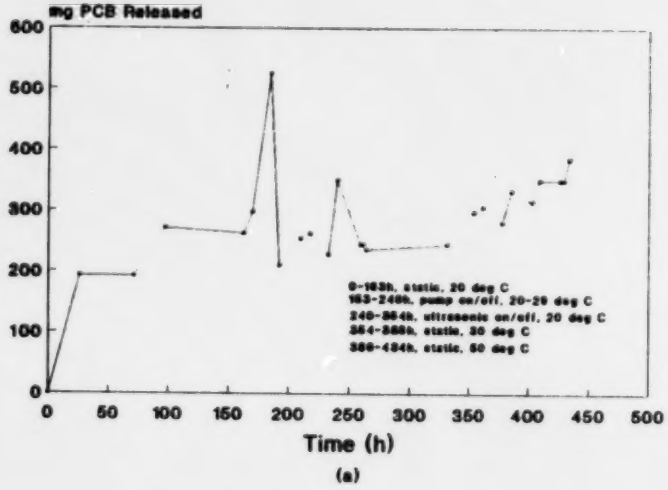
Equation 1 describes the diffusional release at short times from a semi-infinite medium.

Estimated diffusion coefficients are shown in Table 6. Results for both transformers appear to be mutually consistent: the effective diffusivity of PCBs in the papers and pressboard was about 7×10^{-10} and 4×10^{-8} cm^2/s, respectively.

TABLE 6

ESTIMATED DIFFUSION COEFFICIENTS

Material	D (cm^2/s)
177 ppm Transformer	
Pressboard	6.2×10^{-8}
Green Paper	4.1×10^{-10}
Brown Paper	6.2×10^{-10}
1170 ppm Transformer	
Pressboard	1.1×10^{-8}
Paper	1.2×10^{-9}
Wood	4.4×10^{-8}
Plastic	1.2×10^{-9}



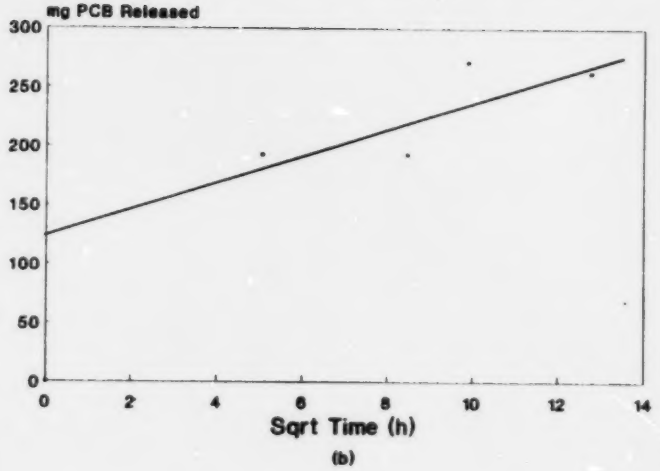


Figure 3 Decontamination of 1170 ppm Transformer

4.0 RELEASE OF PCBs DURING IN-SITU DECONTAMINATION OF TRANSFORMER

The effectiveness of in-situ oil decontamination was assessed using Transformer No. 54251 (see Table 1). This transformer was similar in characteristics and PCB contamination level to the dismantled 1180 ppm transformer. The drained transformer was filled with 14.9 kg (17.5 L) oil which was sufficient to completely immerse its core (the total oil capacity was 27 L). Assuming its PCB inventory to be identical to that of the 1180 ppm transformer, i.e., 0.58 g /4/, the expected PCB level in the fluid at equilibrium was about 39 ppm.

Two sampling lines, one located centrally near the bottom of the casing and the other close to the centre of the coil, allowed oil samples to be withdrawn for PCB analysis. An ultrasonic probe (Braunsonic) installed close to the periphery of the coil was operated intermittently. A Micro-pump capable of circulating fluid at about 1.5 L/min was located outside the casing. The casing was wrapped with an electrical tape to heat the oil.

Figure 3 shows the release behaviour as a function of time. A rapid release of about one third of the PCB inventory occurred initially followed by a slower temperature dependent rate of release. As shown in Figure 3(b), the initial release probably represented a washout effect of the oil present within the interstices and on the external surfaces of the core. Note that the release from the casing surfaces, expected to be rapid (based on earlier observations with core steel) can only account for about 1 mg of the initial release. Following the initial washout, subsequent release was probably governed by diffusion in the porous materials. This explains the ineffectiveness of recirculating the fluid. The effect of recirculation was principally to homogenize the PCB in the oil - prior to activating the pump, the difference in the PCB content of oil samples drawn from the two sampling locations was very significant. Ultrasonic vibration did not appear to be beneficial. Whether this was due to inadequate intensity is not known because separate experiments with and without vibrations were not performed. An increase in temperature from room to 50^0C significantly increased the rate of release. The release rate at the elevated temperature was about 1.5 mg/h.

The fluid contamination level was 22 ppm at the end of the parametric investigation described above. The transformer was then allowed to cool to room temperature and the PCB release monitored over an extended duration. Prior to sampling, the fluid was recirculated briefly. Samples taken at 57 and 87 days from initial immersion had fluid contamination levels of 28 and 29 ppm, respectively. Thus equilibrium appears to have been achieved within about 60 days. Note that the equilibrium level reached was lower than the expected value of 39 ppm (see above); the reason for this is not clear.

The PCB inventory remaining in the transformer after decontamination and subsequent draining would, therefore, be $0.58 - 29 \times 14.9 \times 10^3 \times 10^{-6}$ or

0.15g. The overall DF was thus about 4. Assuming the porous materials to constitute 3.7 wt % of the transformer/4/, the residual contamination in the solid was about 65 ppm. A second drain and soak would thus be required to reduce the contamination below 50 ppm.

5.0 CONCLUSIONS

The use of insulating oil to decontaminate PCB contaminated transformers appears to be feasible. Immersion in oil leads to a uniform redistribution of the PCBs associated with the porous materials. Residual contamination levels in these materials is consistent with their capacity to absorb oil. The release process appears to occur in two distinct steps: an initial washout effect which might be accelerated by fluid agitation followed by a diffusional release where an elevated temperature is beneficial but fluid agitation/convection is not important. In contrast to PCBs in porous materials, adsorbed PCBs on metal surfaces desorb readily; contact times required are in the order of hours rather than days as in the case of the porous materials.

Provided sufficient time for equilibration is allowed, the effectiveness of the decontamination is solely determined by the operating oil to solids ratio. Depending upon the regulatory targets, the quantity of oil for each soaking and the number of oil changes needed could be adjusted to provide the required degree of decontamination.

The decontamination process can be applied directly to an undismantled transformer or as a tail end process to clean up residual contamination in dismantled materials.

6.0 RECOMMENDATIONS

Insulating oil can potentially be used to decontaminate transformers to less than 50 ppm. The process is inherently simple and would require minimal operator intervention. Further, the waste oil can readily be cleaned up using Ontario Hydro's sodium based oil decontamination process. While further process development is strongly recommended, it should, however, be deferred until a complete assessment of existing decontamination technologies is performed. Such an assessment should establish the limitations of the various technologies and their ability to meet the stringent regulatory environment in Ontario both with respect to process emissions as well as residual wastes. A comparison of the economics of these processes with that based on insulating oil should also be performed.

The following work will be required if the above assessment favours further development of the oil based process:

1) establish equilibration times for in-situ decontamination at elevated temperatures,

2) autopsy decontaminated transformers to confirm levels of residual PCBs,

3) determine the effect of reusing contaminated oil on equilibration times,

4) determine diffusion constants for core materials to develop a predictive capability for the rate of release.

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